



### **Nanocomposite Photoelectrochemical Cells**

**Efficiencies greater than those of state-of-the-art cells are predicted.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Improved, solid-state photoelectrochemical cells for converting solar radiation to electricity have been proposed. (In general, photoelectrochemical cells convert incident light to electricity through electrochemical reactions.) It is predicted that in comparison with state-of-the-art photoelectrochemical cells, these cells will be found to operate with greater solar-to-electric energy-conversion efficiencies.

The proposed cells could be fabricated by layering nanocomposites of active particles with organic binders on flexible polymer substrates. Each cell would contain a dye-sensitized semiconductor electrode, a proton-conducting solid electrolyte, and a solid-state pro-

ton-intercalation counter electrode. By designing the cells to rely on protons as the charge carriers, it should be possible to enable the cells to sustain rates of transport and concentrations of charge carriers greater than those of state-of-the-art photoelectrochemical cells designed to rely on hole conduction and organic semiconductors. The proposed cell configuration is expected to minimize the incidence of recombination of holes and electrons, thereby minimizing the energy losses associated with them and thereby, further, contributing to greater energy-conversion efficiencies.

*This work was done by Sri R. Narayan, Andrew Kindler, and Jay F. Whitacre of Cal-*

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*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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### **Ultracapacitor-Powered Cordless Drill**

**Whereas charging of batteries usually take hours, ultracapacitors can be charged in seconds.**

*John H. Glenn Research Center, Cleveland, Ohio*

The figure depicts a portable, hand-held power drill with its attached power-supply unit, in which ultracapacitors, rather than batteries, are used to store energy. This ultracapacitor-powered drill is a product of continuing efforts to develop the technological discipline known as hybrid power management (HPM), which is oriented toward integration of diverse electric energy-generating, energy-storing, and energy-consuming devices in optimal configurations.

Instances of HPM were reported in several prior *NASA Tech Briefs* articles, though not explicitly labeled as HPM except in the most recent such article, which was "Hybrid Power Management" (LEW-17520-1), Vol. 29, No. 12 (December 2005), page 35. To recapitulate from that article: The use of ultracapacitors as energy-storage devices lies at the heart of HPM. An ultracapacitor is an electrochemical energy-storage device, but unlike in a conventional rechargeable electrochemical cell or battery, chemical reactions do not take place during oper-

ation. Instead, energy is stored electrostatically at an electrode/electrolyte interface. The capacitance per unit volume of an ultracapacitor is much greater than that of a conventional capacitor because its electrodes have much greater surface area per unit volume and the separation between the electrodes is much smaller.

HPM offers many advantages over the conventional power-management approach in which batteries are used to store energy. To place the present development in context, it is necessary to reiterate these advantages from the cited previous article:

- Power-control circuits for ultracapacitors can be simpler than those for batteries for two reasons: (1) Because of the absence of chemical reactions, charge and discharge currents can be greater than those in batteries, limited only by the electrical resistances of conductors; and (2) Whereas the charge level of a battery depends on voltage, temperature, age, and load condition, the charge level of an ultracapacitor, like that of

a conventional capacitor, depends only on voltage.

- Whereas a typical battery can be charged and discharged about 300 times, an ultracapacitor can be charged and discharged more than a million times. The longer lifetimes of ultracapacitors contribute to reliability.
- The longer lifetimes of ultracapacitors greatly reduce life-of-system costs, including the indirect costs of maintenance and downtime.
- The longer lifetimes of ultracapacitors reduce adverse environmental effects, inasmuch as it will probably never be necessary to replace and dispose of ultracapacitors in most applications, whereas batteries must be replaced frequently.
- Disposal problems and the associated contributions to life-of-system costs can be reduced because the chemical constituents of ultracapacitors are less toxic and less environmentally harmful than are those of batteries. Indeed, ultracapacitors are somewhat recyclable.



The **Power Pack** attached to the bottom of the handle of the power drill utilizes ultracapacitors, rather than batteries, to store energy.

- Excellent low-temperature performance makes ultracapacitors suitable for storing energy in applications at temperatures too low for batteries.
- The consistent performance of ultracapacitors over time enables reliable operation not possible with batteries.
- Unlike batteries, ultracapacitors can be safely left completely discharged for indefinitely long times.
- Whereas the charge-discharge efficiency in conventional power management using rechargeable batteries is typically about 50 percent, the charge-discharge efficiency in HPM typically exceeds 90 percent.

For the cordless drill, a dedicated charger is used to fully realize the advantages of the ultracapacitors as energy-storage devices. Because of the non-critical nature of charging and dis-

charging of ultracapacitors, this charger is less complex and less costly than would be a battery charger for the same power drill. More spectacularly, taking advantage of the unique charging characteristics of ultracapacitors, this charger can make the ultracapacitor-powered cordless drill ready for operation in seconds, in contradistinction to the several hours needed to recharge batteries.

*This work was done by Dennis J. Eichenberg of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18116-1.*



## Cumulative Timers for Microprocessors

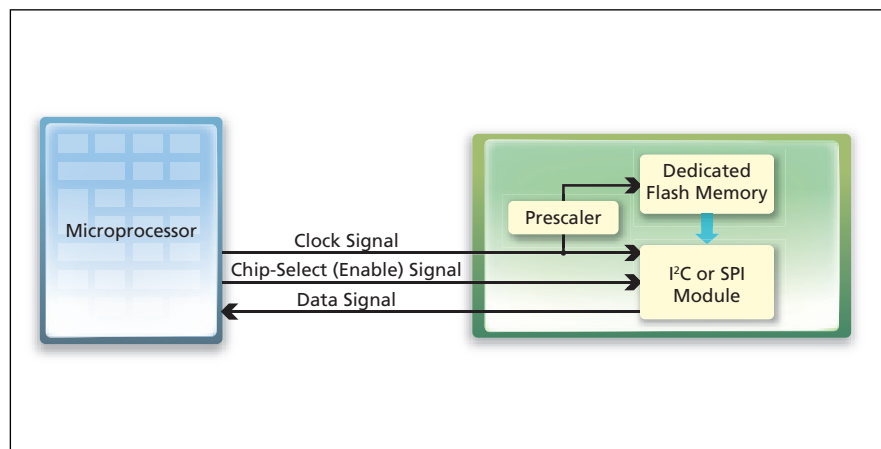
**Accumulated operating times and serial numbers would be displayed.**

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It has been proposed to equip future microprocessors with electronic cumulative timers, for essentially the same reasons for which land vehicles are equipped with odometers (total-distance-traveled meters) and aircraft are equipped with Hobbs meters (total-engine-operating-time meters). Heretofore, there has been no way to determine the amount of use to which a microprocessor (or a product containing a microprocessor) has been subjected. The proposed timers would count all microprocessor clock cycles and could only be read by means of microprocessor instructions but, like odometers and Hobbs meters, could never be reset to zero without physically damaging the chip.

A timer according to the proposal could be either an external device connected to a microprocessor or embedded within the microprocessor. The external implementation could be retrofit to a pre-existing microprocessor. In the external implementation (see figure), the timer would include a prescaler; an inter-integrated-circuit (I<sup>2</sup>C) or a serial peripheral interface (SPI) module; and a flash random-access memory (RAM) that would store a unique serial number and a prescaler-reduced count of clock cycles, both of which could be read over a one- or two-wire bus.

The serial number stored in the flash RAM would serve as the serial number



A **Cumulative Timer** could be added to a microprocessor as an electrically connected external unit. Alternatively, it could be incorporated as an integral part of the microprocessor.

of the microprocessor and of any equipment containing the microprocessor, for purposes of registering any warranty of the equipment and verifying the authenticity of the equipment. On a display generated by the microprocessor, the user could compare the electronically stored serial number with the serial number printed on a label affixed to the equipment and the serial number on the warranty registration and could read the accumulated operating time. Periodically, during normal operation, the microprocessor would attempt to interrogate the flash memory

and would turn itself off if it were unable to read its proper serial number. Upon each such interrogation, the count stored in the flash memory would be incremented.

The internal implementation would function similarly to the external implementation, except that the serial number and the prescaler-reduced count of clock cycles would be stored in either (1) part of the flash RAM used by the rest of the microprocessor or (2) a separate flash RAM dedicated to the timer. It would be necessary to design the microprocessor hardware